US007888230B2

(12) United States Patent
von Kluge

(10) Patent No.: **US 7,888,230 B2**
(45) Date of Patent: **Feb. 15, 2011**

(54) **METHOD OF MAKING AN INTEGRATED CIRCUIT INCLUDING STRUCTURING A MATERIAL**

(75) Inventor: **Johannes von Kluge**, Dresden (DE)

(73) Assignee: **Qimonda AG**, Munich (DE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 344 days.

(21) Appl. No.: **12/121,331**

(22) Filed: **May 15, 2008**

(65) **Prior Publication Data**

US 2008/0315357 A1 Dec. 25, 2008

(30) **Foreign Application Priority Data**

May 15, 2007 (DE) 10 2007 022 748

(51) **Int. Cl.**
H01L 21/20 (2006.01)

(52) **U.S. Cl.** **438/396**; 257/532; 430/296

(58) **Field of Classification Search** 438/396; 257/532, E29.343; 430/296
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,258,691	B1	7/2001	Kim	
6,534,221	B2 *	3/2003	Lee et al.	430/5
6,946,341	B2	9/2005	Joo et al.	
7,027,227	B2 *	4/2006	Chiba et al.	359/619
7,067,385	B2	6/2006	Manning	
7,125,781	B2	10/2006	Manning et al.	
7,557,015	B2	7/2009	Sandhu et al.	
2002/0086479	A1	7/2002	Reinberg	
2005/0245022	A1	11/2005	Gutsche et al.	
2005/0253179	A1	11/2005	Park	
2006/0252224	A1	11/2006	Basceri et al.	
2006/0263968	A1	11/2006	Manning	
2007/0037349	A1	2/2007	Gutsche et al.	

OTHER PUBLICATIONS

Kim et al., "A Mechanically Enhanced Storage node for virtually unlimited Height (MESH) Capacitor Aiming at sub 70nm DRAMs", IEDM Tech. Dig., p. 69-72 (2004).

* cited by examiner

Primary Examiner—Phuc T Dang
(74) *Attorney, Agent, or Firm*—Dicke, Billig & Czaja, PLLC

(57) **ABSTRACT**

A method of making an integrated circuit including structuring a material. The method includes providing an arrangement of three-dimensional bodies. The material is arranged between the bodies and structured directed radiation. The projection pattern of the three-dimensional bodies is transferred into the material. The structured material connects at least two of the three-dimensional bodies.

20 Claims, 4 Drawing Sheets

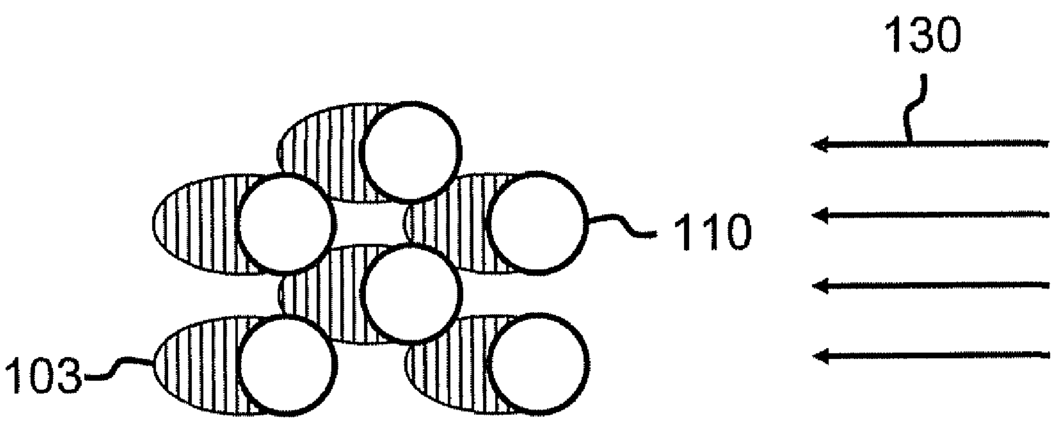


FIG. 1

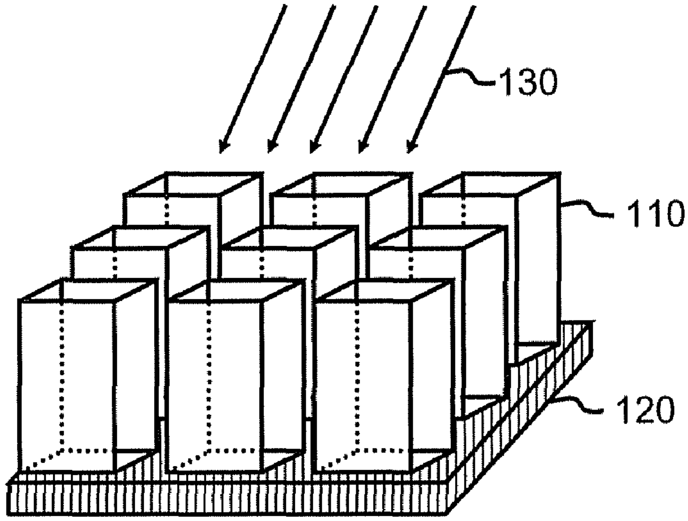


FIG. 2

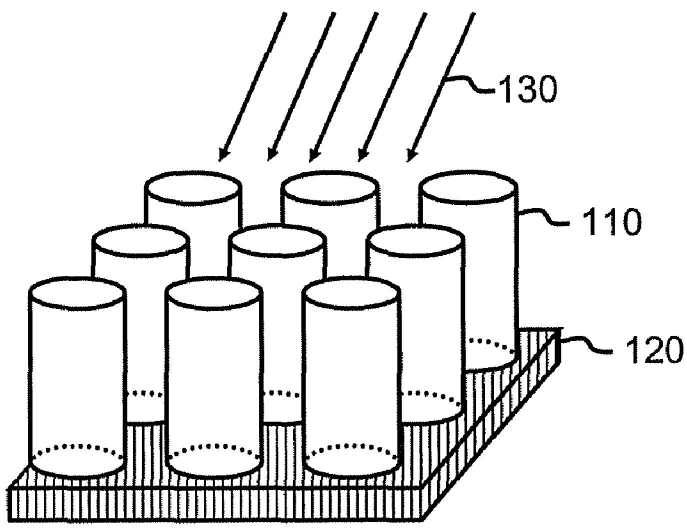


FIG. 3

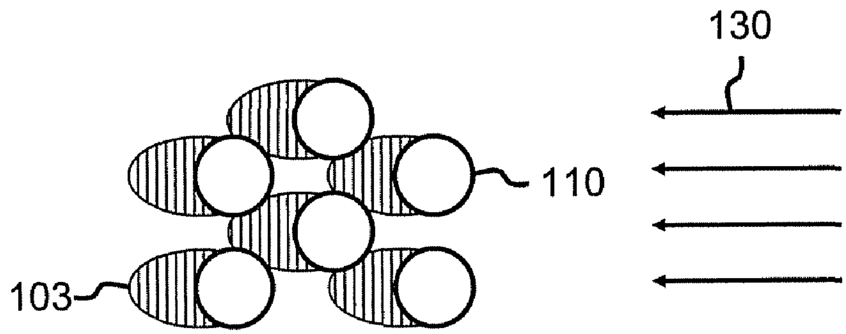


FIG. 4

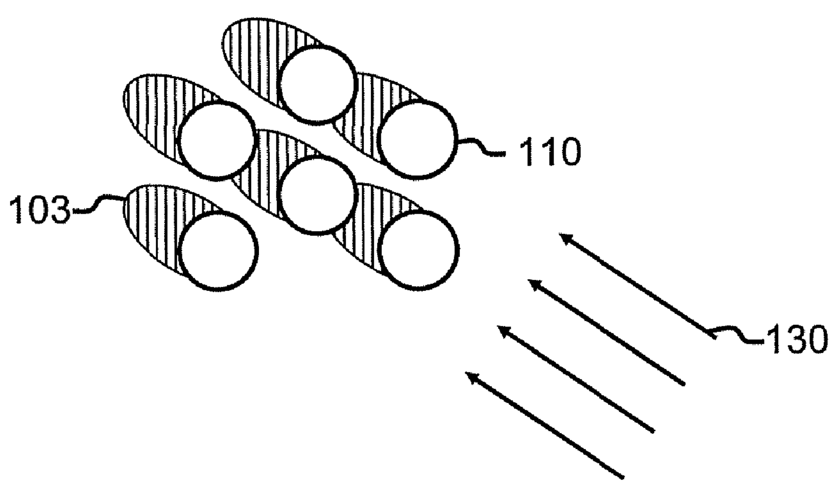


FIG. 5

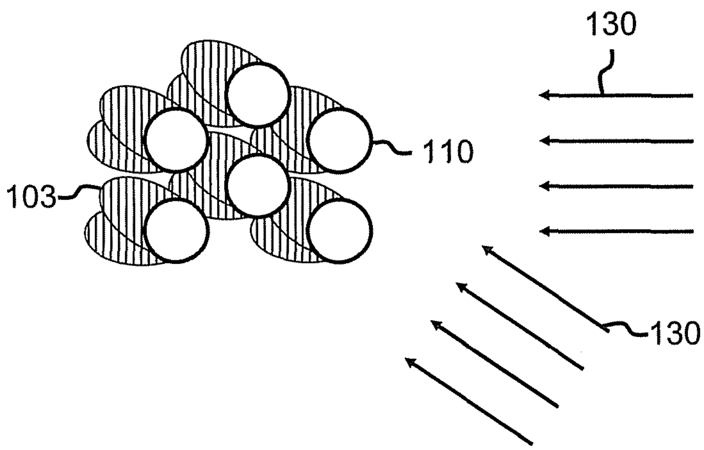


FIG. 6A

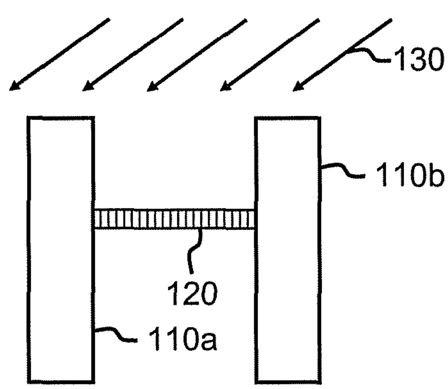


FIG. 6B

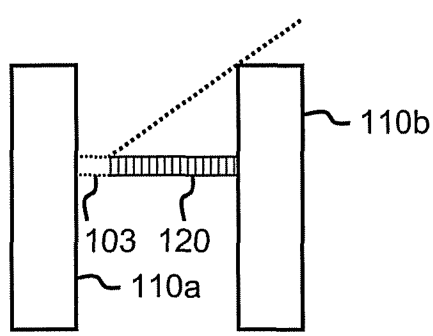


FIG. 7A

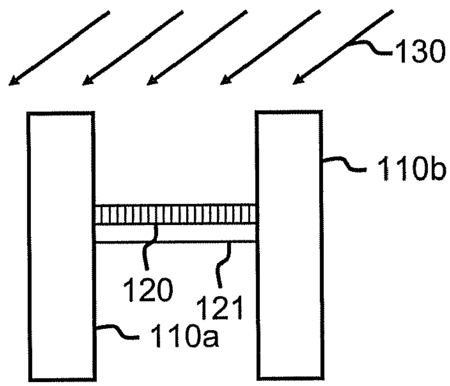


FIG. 7B

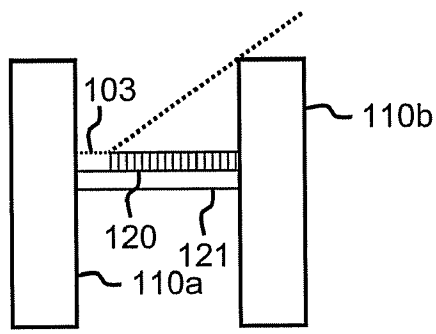
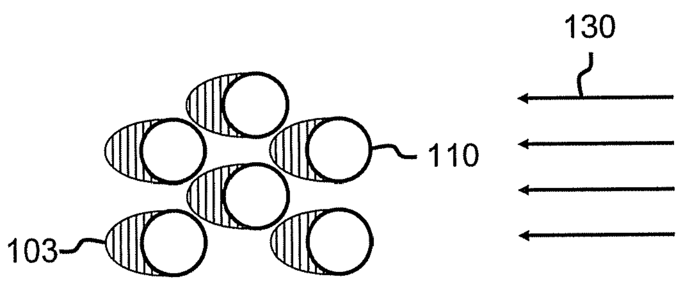


FIG. 8



METHOD OF MAKING AN INTEGRATED CIRCUIT INCLUDING STRUCTURING A MATERIAL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to German Application No. 10 2007 022 748.7-43 filed May 15, 2007, which is incorporated herein, in its entirety, by reference.

BACKGROUND

The following description relates to the technical field of semiconductor components, specifically it refers to a method of structuring a layer in a semiconductor component.

In the following context the term "semiconductor component" relates in general to integrated circuits, chips, as well as single semiconductor components like for example analog or digital circuits or single semiconductor components like semiconductor memory elements, for example, functional storage components (PLAs, PALs etc.) and array storage elements (ROMs or RAMs, especially SRAMs and DRAMs).

Beside other applications, for example, micromechanical components, the method of structuring can be used to manufacture stabilizing support structures of capacitors of DRAM-components. According to the cell concept one may distinguish between trench capacitors and stack capacitors. Trench capacitors are formed in the substrate and therefore are arranged underneath the selection transistors of the respective cell. On the other hand, stack capacitors are arranged above the substrate and above the selection transistors.

In terms of shape, both capacitor types may have a cylindrical form. The cross section may be round or elliptical and does not need to be of the same shape over the axial course of the capacitor. For sake of simplicity, the shape is referred to as tube, whereas different areas and sizes of cross sections at different axial positions are possible. Furthermore the tubes may include an overhang, i.e. they may have a larger cross section in a top portion compared to a lower portion.

To increase the capacitance of a capacitor C

$$C = \varepsilon_o \varepsilon_r \frac{A}{d}$$

with the surface A, the distance between the electrodes d and the dielectric constant $\in_r$, various measures are applied. One measure may be the increase of the aspect ratio of the capacitor tube and thereby the increase of the capacitor surface A.

The structure of the stack capacitors above the substrate leads to the problem of mechanical stability of the capacitor arrangement. For example, a process using liquids (e.g., a wet etch or a wet rinse) may lead to a collapse of the tubes due to capillary forces.

Various techniques are applied for the mechanical stabilization of the stack capacitor.

In general, support structures are introduced which are arranged in an upper portion of the capacitor tube and which connect adjacent tubes with each other. This may prevent a bending of the capacitor tubes. However, it must be ensured that the material underneath the support structure can be at least partly removed. To achieve this, a structuring of the support material needs to be done in order to create openings.

One possibility to structure the support material is the use of the so called mask process. In a first step, a photoresist is deposited. The resist is exposed through a mask and the exposed or unexposed parts of the resist are removed. The structure of the resist layer is transferred in a subsequent step into the support material. Disadvantage of such a method is the need of a mask for this process and additional steps like the deposition of the photoresist, the exposure and the structuring of the resist, etc. are required. This impacts the cost of such a manufacturing process of a semiconductor component.

Kim et al., "A Mechanically Enhanced Storage Node for Virtually unlimited Height (MESH) Capacitor Aiming at sub 70 nm DRAMs", IEDM Tech. Dig., p. 69-72 (2004) illustrates a support structure of a stack capacitor made from silicon nitride. The structuring of the support structure is performed by using the so called spacer technology. A conformal silicon nitride layer is deposited onto the capacitor tube. The support material is subsequently structured by using dry etch step. Using this method, the structuring is self aligned and no mask step is required.

A similar process is proposed by Manning in U.S. Pat. No. 7,067,385. A spacer is used for the structuring of the support material as well.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of embodiments and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and together with the description serve to explain principles of embodiments. Other embodiments and many of the intended advantages of embodiments will be readily appreciated as they become better understood by reference to the following detailed description. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts.

FIG. **1** illustrates a schematic representation of a perspective view of an arrangement of three-dimensional bodies with material between the three-dimensional bodies and a directed radiation.

FIG. **2** illustrates a schematic representation of a perspective view of an arrangement of tubes with a material between the tubes and directed radiation.

FIG. **3** illustrates a top view of an arrangement of tubes with a projection pattern after a directed radiation from a first direction.

FIG. **4** illustrates the same top view as FIG. **3** after a directed radiation from a second direction.

FIG. **5** illustrates a top view of an arrangement of tubes with a projection pattern after directed radiation from two different directions.

FIG. **6**A illustrates a side view of two adjacent tubes and with a material between these two tubes prior to a directed radiation.

FIG. **6**B illustrates a side view of two adjacent tubes and with material between these two tubes after removing the material exposed during the radiation.

FIG. **7**A illustrates a further implementation with a first material and a second material arranged between two adjacent tubes and prior to a directed radiation.

FIG. **7**B illustrates a further implementation with a first material and second material arranged between two adjacent tubes and after removal of the material exposed during the radiation.

FIG. **8** illustrates a top view of an arrangement of tubes with a projection pattern after directed radiation from a first direction.

DETAILED DESCRIPTION

In the following Detailed Description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. In this regard, directional terminology, such as "top," "bottom," "front," "back," "leading," "trailing," etc., is used with reference to the orientation of the Figure(s) being described. Because components of embodiments can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

It is to be understood that the features of the various exemplary embodiments described herein may be combined with each other, unless specifically noted otherwise.

As described in complete detail below, one embodiment of a method of making an integrated circuit or device including a the method for structuring a material includes:

providing an arrangement of three-dimensional bodies with the material between the bodies;

structuring the material by directed radiation,

whereby the projection pattern of the three-dimensional bodies is transferred into the material and the material connects at least two of the three-dimensional bodies.

The term "connecting" does not only refer to the direct mechanical contact between the three-dimensional bodies, but may in a wider meaning also refer to three-dimensional bodies being coupled. In this case, a further material may be arranged between three-dimensional bodies in addition to the structured material. It is also be possible, that a gap exist between the three-dimensional bodies and the structured material.

The directed radiation may, for example, include radiation with ions, electrons or photons. When using ions, the ions may substantially have one direction and may be selected from the group of BF_2, B, P, As, Ge, N_2, N, C, Si, F, In, Sb, He, Ne, Ar, Kr, Xe, or Rn.

The three-dimensional bodies may be formed as tubes. The tubes may include a round or elliptical cross section and may include an overhang.

The material between the three-dimensional bodies may, for example, be selected from the group of silicon oxide, amorphous silicon, silicon nitride or a photoresist.

The material being exposed or being not exposed by the directed radiation and arranged between the three-dimensional bodies may be removed in a separate process step.

In one embodiment, the material between the three-dimensional bodies may have a higher removal rate after the directed radiation compared to the removal rate before the radiation.

In one embodiment, the material between the three-dimensional bodies may also have a lower removal rate after the directed radiation compared to the rate before the radiation.

The material between the three-dimensional bodies can be removed in a separate process using a liquid which may be selected from the group of ammonia, hydrofluoric acid or a solvent to develop a photoresist.

The material between the three-dimensional bodies may be removed by using a plasma in a separate process.

The material between the three-dimensional bodies may be eroded by the directed radiation.

The arrangement of three-dimensional bodies may be an arrangement of stack capacitors and the material between the three-dimensional bodies may be a support structure between the stack capacitors. The material between the three-dimensional bodies can as well be used to structure a second material; the second material then forming the support structure between these stack capacitors.

One embodiment provides a material which is structured by a projection of an arrangement of three-dimensional bodies by directed radiation wherein the projection pattern of the three-dimensional bodies is transferred into the material and the material connects at least two of the three-dimensional bodies.

One embodiment provides an arrangement of stack capacitors with a material being structured by projection of an arrangement of stack capacitors by directed radiation, wherein a projection pattern of the stack capacitors is transferred into the material and the material connects at least two of the stack capacitors. The material between the stack capacitors may as well be used to structure a second material.

One embodiment provides an integrated circuit, which includes a material, the material being structured by the inventive method. The integrated circuit may at least include two stack capacitors and a stack capacitor and a material which has been structured by the inventive method.

One embodiment provides a DRAM component including stack capacitors which are connected by a material which has been structured by the inventive method.

The invention is described in detail in the following with reference to the drawings. The drawings illustrate embodiments of the invention. However, the invention can be realized in various implementations and it is not intended to limit the invention to the implementations illustrated. Moreover, the implementations serve to formulate the disclosure in a diligent and accurate manner and to enable the persons skilled in the art to exercise the invention. The drawings are not to scale, but shall illustrate the necessary elements for understanding the invention in a schematic way. The layer thicknesses are not to scale, as well as the diameters and heights of the three-dimensional bodies or tubes, and therefore as well their aspect ratio. The angle of the radiation is arbitrary and is illustrated to demonstrate the inventive principle.

FIGS. **1** and **2** illustrate a general arrangement to represent the inventive concept. An arrangement of three-dimensional bodies **110** with a material **120** in between is subjected to directed radiation **130**. It is intended to structure the material **120** between the tubes **110** by using the inventive concept.

The inventive concept is discussed in more details in FIG. **2** according to one embodiment using tubes as three-dimensional bodies **110** and using directed radiation **130** by ions, electrons or photons.

A projection pattern **103** is generated on the material **120** by the arrangement of tubes **110** subjected to the directed radiation **130**. The projection pattern depends on the angle of incidence of the directed radiation **130** and the structure and arrangement of the tubes **110**.

FIG. **3** illustrates an example of a top view of the arrangement of tubes **110** with a projection pattern **103** after directed radiation **130** from a first direction. The projection pattern of the tubes **110** is transferred into the material **120**.

In one embodiment, the removal rate of the material **120** is modified by the radiation **130**. On the one hand, it is possible that the material **120** has an increased removal rate after radiation **130** compared to the same material **120** without radiation **130**. In a subsequent process, this selectivity of the removal rate is used to remove the material **120** being irradiated by the ions **130**. The remaining structure **103** of the material **120** shall be structured so as to generate a connection between at least two of the tubes **110** by the material **120**.

The term "connect" is not limited in this case to direct contact between the three-dimensional bodies **110** but may also mean that the three-dimensional bodies **110** are coupled with each other. In this case, a further material can be arranged between the three-dimensional bodies **110** in addition to the structural material **120**. It is as well possible, that a gap between the three-dimensional bodies **110** exist in addition to the structured material **120**.

The term "removal rate" is intended to have a general meaning. The exposed or non exposed material **120** can be removed for example chemically, mechanically, by use of a solvent or a developer.

In one embodiment, the removal rate of the material **120** is modified by the radiation **130**. It is as well possible that the material **120** may have a lower removal rate after radiation **130** compared to the same material **120** without radiation **130**. In a further step, this selectivity of the removal rate is used to remove the material **120** not irradiated by the ions **130**. The remaining structure **103** of the material **120** shall be structured so as to form a connection between at least two tubes **110** by the material **120**.

In one embodiment, a liquid may be used to remove the material **120** irradiated by ions **130**.

In one embodiment, a "dry etching step" using a plasma can be used to remove the irradiated or non-irradiated material **120**. In this case, the removal through an isotropic etch component can be done by radicals generated in a plasma. It is as well possible to use a removal by an anisotropic etch component from accelerated ions of a plasma boundary layer. A combination of isotropic and anisotropic components may be used to remove the irradiated or the non-irradiated material **120** by using a plasma.

In one embodiment, the material **120** is eroded directly through the radiation **130**. Ions may be used for the radiation **130**. The material **120** irradiated by the ions **130** will thereby be removed. The remaining structure **103** of the material **120** shall be formed so as to connect at least two tubes **110** by the material **120**.

FIG. **4** illustrates, for example, a top view of an arrangement of tubes **110** with a projection pattern **103** after radiation **130** from a second direction. The projection pattern **103** of the tubes **110** is transferred into the material **120**.

FIG. **5** illustrates, for example, a top view of an arrangement of tubes **110** with a projection pattern **103** after radiation **130**, wherein the radiation **130** is performed from two different directions. The radiation **130** can be performed in parallel from two different directions or sequentially using two subsequent processes.

The combination of different angles of incidence of the ions and different directions may not be limited. They may be selected to provide a projection pattern **103** which is optimized for the underlying application in order to form a connection between at least two tubes by the material **120**.

FIGS. **6**A and **6**B illustrate a side view of two adjacent tubes **110***a* and **110***b* with a material **120** arranged between this two tubes prior to a radiation **130**, and after removal of the material exposed to the radiation, respectively. The directed ions **130** are blocked by the right tube **10***b* thereby forming two areas of different exposure in the material **120**. The area **103** of the material **120** is irradiated by the ions **130**, while the remaining material **120** is not.

FIGS. **7**A and **7**B illustrate a similar side view compared to FIGS. **6**A and **6**B of two adjacent tubes **110***a* and **110***b* with a first material **120** arranged between these two tubes and a second material **121** underneath the first material **120**. The first material **120** is structured using the inventive concept, and may be used as a hard mask for structuring the second material **121**.

The shape of the tubes **110** can have a constant cross section along the axial course or may vary over it. The tubes **110** may have a larger cross section in a portion above the material **120** compared to a portion located directly at the material **120**, i.e. they may form an overhang above the material **120**. The method is suitable for the projection of three-dimensional bodies **110** having an arbitrary shape.

The inventive structuring method can be used to manufacture support structures of capacitors of DRAM components. These capacitors may be so called "stack capacitors" which require a support structure for mechanical stabilization.

The material **120** forms in this case the support structure. The tubes **110** form, at least partially, the stack capacitors. The tubes **110** may in this case form the first electrode of the stack capacitors. The first electrode is formed in a fill material, also called mould material. In an upper portion of the first electrode, a layer or a system of layers is deposited, which later forms the support structure.

In order to be able to remove the mould material at least partially in a subsequent step, the layer or the system of layers of the support structure needs to be structured. It may in this case be advantageous to provide openings of maximum width in order to be able to remove the underlying mould material in the easiest possible way. With the help of the inventive method the structuring of the support structure of stack capacitors may be performed in an advantageous way.

The stack capacitors may be present in various different two-dimensional arrangements. One arrangement may be a hexagonal pattern. It is possible, that this pattern is not a purely periodic arrangement, but the pattern may include periodic and non-periodic regions as well.

The material **120** may be selected from the group silicon oxide, amorphous silicon, silicon nitride or a photoresist. Silicon nitride may have advantages when forming stack capacitors.

The ions may be selected from the group of BF_2, B, P, As, Ge, N_2, N, C, Si, F, In, Sb, He, Ne, Ar, Kr, Xe or Rn. From this group the elements He, Ne, Ar, Kr, Xe or Rn may be advantageously used in the case of a direct erosion of the material **120** according to an implementation of claim **15**. For example, Ar may be used due to its inert properties and the mass adaption for mechanical removal, so called "sputtering". In one implementation, a liquid selected from the group of ammonia, hydrofluoric acid, or a developer of photoresist may be used in the selective removal of the material **120**.

FIG. **8** illustrates, for example, a top view of an arrangement of tubes **110** with a projection pattern **103** after directed radiation **130** from one direction. The projection pattern **103** of the tubes **110** are transferred into the material **120**. In this case, the projection pattern **103** is only connected directly with one of the tubes **110** and the tubes **110** are coupling with each other through a gap. This gap may be filled with a material. In the case that the gap is not filled, the tubes **110** are allowed to move sideways, but are limited in sideway movement by the material **120**.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A method of making an integrated circuit including structuring a material, the method comprising:

providing an arrangement of three-dimensional bodies with the material arranged between the bodies; and

structuring the material by directed radiation,

whereby the projection pattern of the three-dimensional bodies is transferred into the material and the structured material connects at least two of the three-dimensional bodies.

2. The method of claim 1, wherein the directed radiation comprises a radiation by one of the group of ions, electrons, or photons.

3. The method of claim 2, wherein the radiation substantially has one direction.

4. The method of claim 2, wherein the directed radiation comprises a radiation with ions selected from the group of BF_2, B, P, As, Ge, N_2, N, C, Si, F, In, Sb, He, Ne, Ar, Kr, Xe, or Rn.

5. The method of claim 1, wherein the three-dimensional bodies comprise tubes.

6. The method of claim 5, wherein the tubes comprise having a round or an elliptical cross-section.

7. The method of claim 5, wherein the tubes comprise having an overhang.

8. The method of claim 1, comprising selecting the material arranged between the structures from the group of silicon oxide, amorphous silicon, silicon nitride, or a photoresist.

9. The method of claim 1, comprising modifying a removal rate of the material by the directed radiation and one of the exposed or non-exposed portions of the material is removed in a separate process.

10. The method of claim 9, wherein the material arranged between the three-dimensional bodies comprises a material with a higher removal rate after radiation compared to the removal rate prior to radiation.

11. The method of claim 9, wherein the material arranged between the three-dimensional bodies comprises a material with a lower removal rate after radiation compared to the removal rate prior to radiation.

12. The method of claim 9, comprising removing in the separate process the material using a liquid.

13. The method of claim 12, comprising selecting the liquid from the group of ammonia, fluoric acid, or a developer for photoresists.

14. The method of claim 9, comprising removing in the separate process the material using a plasma.

15. The method of claim 1, comprising eroding the material by the directed radiation.

16. A method of making an integrated circuit including structuring a material, the method comprising:

providing an arrangement of three-dimensional bodies with the material arranged between the bodies; and

structuring the material by directed radiation,

whereby the projection pattern of the three-dimensional bodies is transferred into the material and the structured material connects at least two of the three-dimensional bodies, and

wherein the arrangement of three-dimensional bodies forms part of stack capacitors and the material forms part of a support structure arranged between the stack capacitors.

17. A method of making an integrated circuit including structuring a material, the method comprising:

providing an arrangement of three-dimensional bodies with the material arranged between the bodies; and

structuring the material by directed radiation,

whereby the projection pattern of the three-dimensional bodies is transferred into the material and the structured material connects at least two of the three-dimensional bodies, and

wherein the arrangement of three-dimensional bodies forms stack capacitors and the material is used to structure a second material forming a support structure arranged between the stack capacitors.

18. An integrated circuit comprising:

a material, wherein the material is structured by the method of claim 1.

19. An integrated circuit comprising:

at least two stack capacitors and a material, wherein the material is structured by the method of claim 1.

20. A device comprising:

a DRAM component with a plurality of stack capacitor being connected by a material, wherein the material is structured by the method of claim 1.

* * * * *